

EXPRESS MAIL NO.: EV296620406US

**APPLICATION FOR UNITED STATES PATENT**

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**Title:** **ARTICULATING CONSTANT FORCE FINISHING TOOL  
ACTUATOR**

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**SPECIFICATION**

## ARTICULATING CONSTANT FORCE FINISHING TOOL ACTUATOR

### Field of the Invention

[0001] The present invention pertains generally to apparatus for finishing manufactured goods, and more particularly to an apparatus for maintaining a constant force between a finishing tool and a workpiece.

### Background of the Invention

[0002] In the manufacture or restoration of various products, it is often desirable to perform a finishing operation, such as buffing, grinding or polishing. For example, in the manufacture or restoration of fine jewelry, it is often desired to buff precious metal components to achieve a fine finish for aesthetic appearance. During such finishing operations, it is generally important not to apply excessive pressure of the finishing tool against the workpiece, which would otherwise cause unwanted excessive removal of material from the workpiece. Optimally, it is desired to maintain contact

between the workpiece and the finishing tool at a known and constant force.

[0003] Prior devices for maintaining a constant force between a finishing tool and a workpiece have typically involved complex mechanical devices, often incorporating electronic controls and feedback systems. The complexity of these prior devices presents an increased likelihood of malfunctioning and makes them expensive to purchase and maintain, often to the point that use of the devices is prohibitive for economic reasons. By way of example, an automated finishing system might utilize a programmable computer-controlled robotic arm to engage a workpiece against a stationary finishing tool with a constant force. Such a configuration generally requires some type of force feedback to an appropriately programmed controller, as well as complicated programming code necessary to manipulate the robotic arm to engage the workpiece with a constant force. The time, effort, and equipment necessary to achieve the desired result of constant force finishing with this type of system is likely to increase the cost to an extent that use of such a device is prohibited in many applications.

[0004] In some applications, however, it may be desired to move a finishing tool over a workpiece to finish a large area of the workpiece, or to finish multiple surfaces on a workpiece. When several pieces of the same type of workpiece are to be finished in this manner, such finishing operations are particularly suited to use of a robotic manipulator to articulate the finishing tool over the appropriate surfaces of the workpiece.

The problem remains to ensure that the finishing tool is maintained in contact with the workpiece at a constant force without requiring complicated programing of the robotic manipulator or complex devices such as those described above.

[0005] There is thus a need for a simple apparatus for maintaining a constant force between a finishing tool and a workpiece wherein the finishing tool may be articulated over the workpiece by a robotic manipulator and wherein the apparatus overcomes drawbacks of the prior art, such as those described above.

**Summary of the Invention**

[0006] The present invention provides an apparatus for supporting a finishing tool on a robotic manipulator and for maintaining a constant force between the finishing tool and a workpiece as the robotic manipulator articulates to move the finishing tool relative to the workpiece. Advantageously, the apparatus maintains constant force engagement between the finishing tool and the workpiece without requiring complex feedback systems or special programing of the robotic manipulator.

[0007] In one aspect of the invention, the apparatus includes a biasing device that is couplable to the operative end of a robotic manipulator. A support arm is rotatably coupled to the biasing device and has a tool holder at one end for supporting a finishing tool. The biasing device is configured to move the support arm toward the workpiece, such that the finishing tool engages the workpiece with a constant force as the robotic manipulator articulates to move the finishing tool over the surface of the workpiece.

[0008] In another aspect of the invention, the biasing device includes a rotary actuator having an output shaft coupled to the support arm. The output shaft is caused to rotate with a constant torque, whereby the support arm rotates to move the finishing tool into engagement with the workpiece. As the finishing tool moves over the workpiece, the constant torque applied to the support arm maintains constant force engagement between the finishing tool and the workpiece.

[0009] In an exemplary embodiment, the rotary actuator is actuatable by a source of pressurized air. In another exemplary embodiment, the rotary actuator is a rotary hydraulic device actuatable by pressurized hydraulic fluid. Pressure regulators coupled between the actuators and the pressure sources ensure that the torque of the output shaft is kept constant. The rotary actuator may comprise a rack-and-pinion arrangement, or it may be a vane-type rotary device.

[0010] The features and objectives of the present invention will become more readily apparent from the following Detailed Description taken in conjunction with the accompanying drawings.

#### Brief Description of the Drawings

[0011] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with a general description of the invention given above, and the detailed description given below, serve to explain the invention.

[0012] FIG. 1 is a perspective view of an articulating constant-force tool actuator according to the present invention;

[0013] FIG. 2 is a perspective view of the tool actuator of FIG. 1, depicted in various positions relative to the workpiece;

[0014] FIG. 3 is a cross-sectional view of the tool actuator depicting exemplary components; and

[0015] FIG. 4 is a cross-sectional view similar to FIG. 3, illustrating another exemplary apparatus according to the present invention.

**Detailed Description**

[0016] Referring to FIG. 1, there is shown an exemplary apparatus 10 for maintaining a constant force engagement between a finishing tool 12 and a workpiece 14 while the finishing tool 12 is articulated to move along at least one surface of the workpiece 14. The apparatus 10 includes a biasing device 16 which may be connected to the operative end 18 of a robotic manipulator 20. The robotic manipulator 20, is programmed or controlled, as known in the art, to move the finishing tool 12 to various positions and/or locations relative to the workpiece 14.

[0017] The apparatus 10 further includes a support arm 22 coupled to the biasing device 16 and extending outwardly from the biasing device 16. The finishing tool 12, such as a buffing, grinding, or polishing wheel, is disposed on a first end of the support arm 22 and is coupled to the support arm 22 by a tool holder 26. The finishing tool 12 may be driven by a motor (not shown) mounted directly on the support arm 22, adjacent the finishing

tool 12, or alternatively mounted on another portion of the apparatus 10 and driven, for example, by a belt, as known in the art. While the finishing tool 12 has been depicted in the exemplary embodiment herein as a disk or wheel coupled to the support arm 22 for rotational movement, it will be understood by those of ordinary skill in the art that the finishing tool 12, tool holder 26 and motor may have various other configurations for finishing a workpiece 14 as known in the art. As a non-limiting example, the finishing tool 12 may be coupled to a motor for vibratory, orbital, or oscillatory motion.

**[0018]** Advantageously, the biasing device 16 is configured to move the support arm 22 to engage the finishing tool 12 against the workpiece 14 at a constant force. In the exemplary embodiment shown, the biasing device 16 rotates the support arm 22 in the direction of arrow 28, such that an edge 30 of the finishing tool 12 engages the workpiece 14. While the apparatus 10 has been depicted here in a configuration wherein the support arm 22 is biased to move in a single rotational direction, it will be recognized that the biasing device 16 may alternatively be configured to rotate the support arm 22 in both directions.

**[0019]** Because the robotic manipulator 20 may be programmed to move to various locations within a three-dimensional coordinate system, the robotic manipulator 20 may be used to move the finishing tool 12 relative to the workpiece 14 while the biasing device 16 maintains constant force engagement between the finishing tool 12 and the workpiece 14, as best depicted in FIG. 2. In FIG. 2, the apparatus 10 is depicted in a first position

P1 in engagement with a first surface 40 of the workpiece 12. In this position, the robotic manipulator 20 may move the finishing tool 12 along the first surface 40 of the workpiece 14 in a direction indicated by arrow 42. FIG. 2 also depicts the apparatus 10 in a second position P2 in engagement with a second surface 44 of the workpiece 14 wherein the robotic manipulator 20 may be articulated to move the finishing tool 12 along the second surface 44 of the workpiece 14 in the direction of arrow 46. The apparatus 10 is also depicted in a third position P3 wherein the finishing tool 12 is in engagement with a third surface 48 of the workpiece 14 and whereby the robotic manipulator 20 may be articulated to move the finishing tool 12 along the third surface 48 of the workpiece 14 as indicated by directional arrow 50. While only three different positions of the apparatus are depicted in FIG. 2, it will be recognized by those of ordinary skill in the art that the robotic manipulator may be articulated to cause the finishing tool to engage various other surfaces of the workpiece, or to be moved in various linear or curvilinear motions while the biasing device maintains the finishing tool in constant force engagement with the workpiece.

[0020] Referring to FIGS. 1 and 2, the apparatus 10 further includes a counterweight 60 provided on a second end 62 of the support arm 22 to offset the mass of the tool holder 26 and the finishing tool 12 disposed on the first end 24 of the support arm 22. In the exemplary embodiment shown, the counterweight 60 is adjustable to slide along the support arm 22, whereby the counterweight 60 may be adjusted to accommodate

various finishing tools which may be selectively coupled to the tool holder 26 at the first end 24 of the support arm 22. Alternatively, the counterweight 60 may also be selected or adjusted to accommodate the weight of a motor or other components or devices supported at the first end 24 of the support arm 22. Advantageously, the counterweight 60 offsets the mass of the finishing tool 12 and other components at the first end 24 of the support arm 22, whereby the biasing device 16 is able to maintain constant force engagement between the finishing tool 12 and the workpiece 14 while the robotic manipulator 20 articulates to move the finishing tool 12 to various positions on the workpiece 14. Specifically, the adjustable counterweight 60 accounts for the mass load of these components as the apparatus 10 is articulated such that the support arm is biased in a direction of the gravitational loading of these components without the need for complex force actuators or feedback mechanisms.

[0021] Referring now to FIG. 3, there is shown a cross-sectional view depicting an exemplary embodiment of a biasing device 16 according the present invention. The biasing device 16 comprises a rotary actuator 70 having rack and pinion gears 72, 74 operatively coupled to at least one piston member 76 and disposed within a housing 78. The housing 78 is mounted to the operative end 18 of the robotic manipulator 20 by a mounting plate 80. An output shaft 82 coupled to the pinion gear 74 extends from the housing 78 and is coupled to the support arm 22 by a second mounting plate 84. A rotary bearing 86 is coupled between the housing 78 and the second mounting plate 84 whereby rotation of the

output shaft 82 is transferred to the support arm 22 to move the support arm 22 in the direction of rotation of the output shaft 82. The rotary bearing 86 may be a cross-roller bearing, or any other suitable bearing capable of supporting an axial load while permitting rotation of support arm 22. In the exemplary embodiment shown, an outer race 88 of the rotary bearing 86 is secured by fasteners 90 to the housing 78, and the second mounting plate 84 is secured by fasteners 90 to an inner race 92 of the rotary bearing 86. Rolling elements 94 between the outer and inner races 88, 92 allow the second mounting plate 84 to rotate with the output shaft 82, whereby support arm 22 coupled to mounting plate 84 also rotates with output shaft 82.

[0022] In use, pressurized air or hydraulic fluid is supplied to the rotary actuator 70 to cause the pistons 76 to move in a desired direction, thereby rotating the shaft 82 and support arm 22. Advantageously, the pressure of the pressurized air or hydraulic fluid supplied to the rotary actuator 70, is controlled by a pressure regulator (not shown) such that the support arm 22 is moved to engage the finishing tool 12 with the workpiece 14 at a constant force.

[0023] FIG. 4 depicts another exemplary biasing device 16a according to the present invention, wherein components similar to those in FIGS. 1-3 have been similarly numbered. In this embodiment, the biasing device 16a is a vane-type rotary actuator configured to operate under the action of pressurized fluid provided to the rotary actuator via fluid inlet and outlet ports 100, 102. In the exemplary embodiment shown, the rotary actuator

includes a vane 104 disposed within housing 78 and coupled to output shaft 82, whereby the output shaft 82 is caused to rotate under the action of the pressurized fluid, as known in the art.

[0024] While the present invention has been illustrated by the description of the various embodiments thereof, and while the embodiments have been described in considerable detail, it is not intended to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. The invention in its broader aspects is therefore not limited to the specific details, representative apparatus and methods and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the scope or spirit of Applicant's general inventive concept.

WHAT IS CLAIMED IS: